Mon. Not. R. Astron. Soc. 266, L51–L53 (1994)

RXJ 0929.1 − 2404: an eclipsing magnetic cataclysmic variable

K. Sekiguchi,[1] Y. Nakada[2] and B. Bassett[3]
[1] *South African Astronomical Observatory, PO Box 9, Observatory 7935, South Africa*
[2] *Kiso Observatory, Institute of Astronomy, University of Tokyo, Mitake, Kiso-gun, Nagano 397-01, Japan*
[3] *Department of Applied Mathematics, University of Cape Town, Rondebosch 7700, South Africa*

Accepted 1993 November 26. Received 1993 November 23; in original form 1993 September 23

ABSTRACT
Optical photometry of the X-ray source RXJ 0929.1 − 2404 reveals deep recurrent eclipses. Observations presently available are consistent with RXJ 0929.1 − 2404 being a polar with an orbital period of 3.39 h, placing it somewhat above the cataclysmic variable 'period gap'. In fact, this establishes RXJ 0929.1 − 2404 as the only eclipsing polar with a period above the 'period gap'.

Key words: binaries: eclipsing – stars: individual: RXJ 0929.1 − 2404 – novae, cataclysmic variables – X-rays: stars.

1 INTRODUCTION

An optical counterpart of the X-ray source RXJ 0929.1 − 2404 ($\alpha = 9^h29^m07^s$, $\delta = -24°04'56''$; epoch 2000.0), detected during the *ROSAT* All Sky Survey (RASS), was identified by one of us during an optical identification programme of *ROSAT* Galactic Plane Survey (RGPS) sources (Buckley et al., in preparation). The discovery spectrum of RXJ 0929.1 − 2404 showed strong emission lines of the Balmer series, as well as He II λ4686-Å and He I lines, which is typical of a cataclysmic variable. In an effort to ascertain the nature of this object, we undertook follow-up optical observations at the South African Astronomical Observatory (SAAO), including a series of CCD photometric observations. Here we report preliminary results of our observations of RXJ 0929.1 − 2404 up to 1993 January. CCD observations obtained in 1993 January show deep recurrent eclipses.

2 OBSERVATIONS

2.1 A low-resolution spectrum

A low-resolution spectrum (FWHM ~7 Å; covering $\lambda\lambda$3400–7200 Å) of RXJ 0929.1 − 2404 was obtained using a grating spectrograph and the Intensified Photon Counting Reticon detector attached to the 1.9-m telescope at the SAAO, Sutherland, on 1992 May 28. A single exposure of 30 min was taken when the visual magnitude estimated from the spectrum was $V = 16.7$. The spectrum (Fig. 1) shows strong emission lines of the Balmer series, and He II λ4686-Å and He I lines, superimposed on a blue continuum. Strong He II λ4686-Å emission lines are a common feature of the magnetic cataclysmic variable. Also, the Balmer jump in emission and the O III λ3444-Å Bowen fluorescence line are evident in the spectrum. This spectrum is very similar to that of the polar RE 1938 − 461 (Buckley et al. 1993).

2.2 CCD photometry

RXJ 0929.1 − 2404 was observed with the UCL–SAAO CCD camera on the 1.0-m telescope at Sutherland. Johnson B and V and Cousins R_c and I_c frames were obtained on 1992 December 25, and time-series observations with integration times of 300 s in the I_c band were taken on five nights between 1993 January 19 and 26. All these observations were performed under photometric conditions. The CCD frames were reduced using the DoPHOT reduction package (Mateo & Schechter 1989). B, V, R_c and I_c magnitudes of the stars on the frames taken on 1992 December 25 were derived using observations of E-region standards (Menzies et al. 1989) immediately before and after the object frames were taken. The standard magnitudes of RXJ 0929.1 − 2404 taken during the phase $0.41 < \phi < 0.68$ (see below) were $B = 17.40$, $V = 17.03$, $R_c = 16.66$ and $I_c = 16.48$. For the time-series observations, three stars on the frames were used as frame standard stars, which were then used to derive I_c magnitudes of RXJ 0929.1 − 2404. These comparison stars are labelled A, B and C on the finding chart (Fig. 2). The rms scatter of the differential magnitudes of these comparison stars during our observations was < 0.01 mag.

The I_c-band light curves for RXJ 0929.1 − 2404 on five different nights are shown in Fig. 3. Although our data have poor temporal resolution, a change in the brightness from $I_c \sim 16.4$ to $I_c \geq 18.5$ for approximately 10 min during eclipse is evident. The eclipses were observed on every night. On January 21 two eclipses, separated by about 3.4 h, were observed. Poor coverage of our photometric data does not allow us to obtain the ephemeris of the system with high

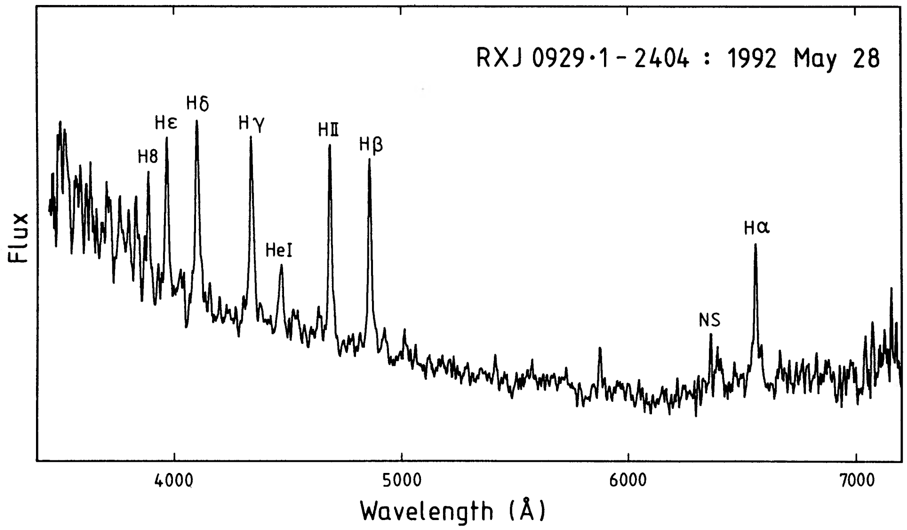

Figure 1. Spectrum (FWHM ~7 Å) of RXJ 0929.1 − 2404, obtained on 1992 May 28.

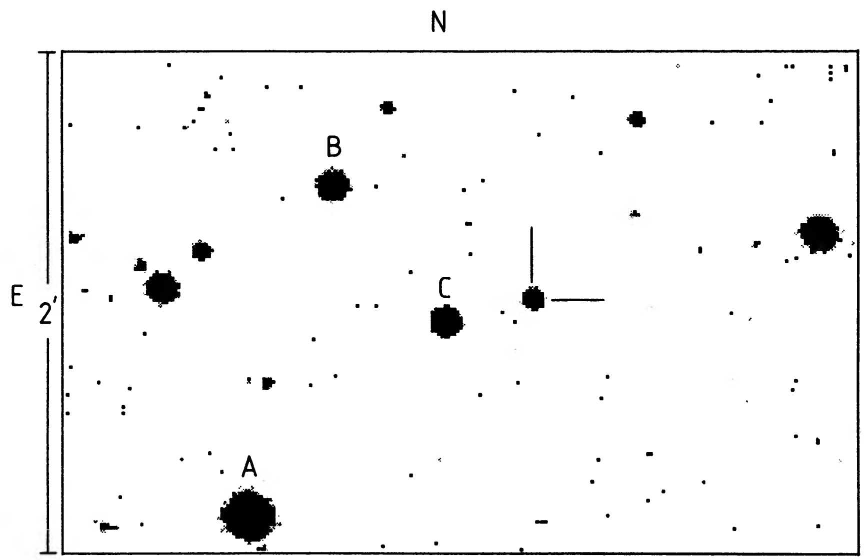

Figure 2. The grey-scale CCD (I_c) image of the field of RXJ 0929.1 − 2404 obtained with the SAAO 1.0-m telescope. The stars marked A, B and C were used as comparisons for differential photometry.

accuracy. A tentative photometric period of 203.39 ± 0.37 min was derived from our I_c data in 1993 January. In Fig. 4 the data are shown folded over this period. The light curves look very similar to those of the AM Herculis binary (polar) RXJ 2107.9 − 0518 (Schwope, Thomas & Beuermann 1993). A tentative eclipse ephemeris established from our data is

$$T_{ecl}(\mathrm{HJD}) = 244\,9007.5879(0.0014) + 0.141\,24(0.000\,26)E, \tag{1}$$

where T_{ecl} is the epoch of the eclipse centres.

Our time resolution of 5 min is not sufficient to resolve ingress into and egress from each eclipse event. Thus the white dwarf radius, and hence the mass, cannot be constrained by our data. However, a maximum limit of the full width of the eclipses in the I_c band of 0.06 in phase (thus the eclipse half-angle $\phi_{1/2} < 11°$) can be obtained from Fig. 4. Use of a relation between the mass ratio $q = M_2/M_{WD}$ and the orbital inclination i of the system for known eclipse width (Chanan, Middleditch & Nelson 1976) gives an upper limit of i for fixed mass ratio. The relationships between secondary mass and period in Patterson (1984) give $M_2 = 0.31\ M_\odot$. Thus the upper limit of the orbital inclination

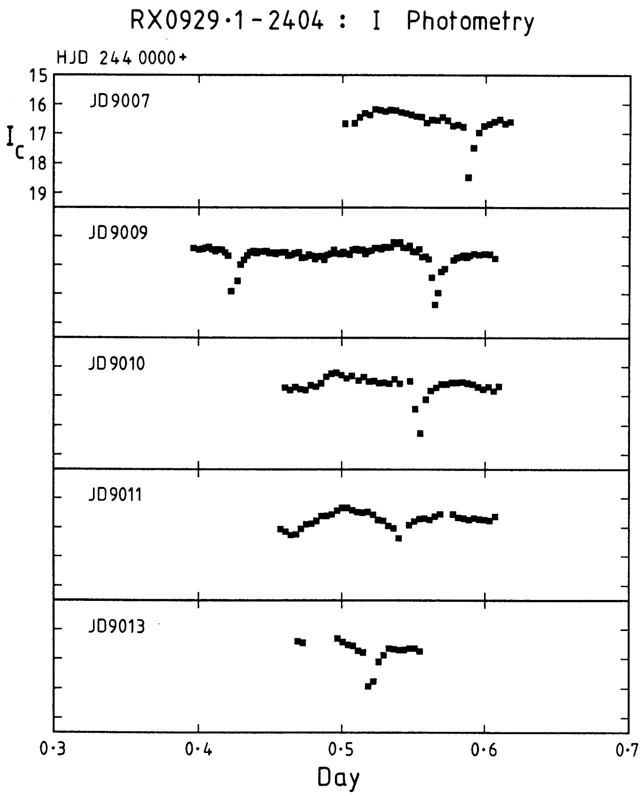

Figure 3. I_c photometry of RXJ 0929.1 – 2404 obtained on 1993 January 19–25 with the SAAO 1.0-m telescope.

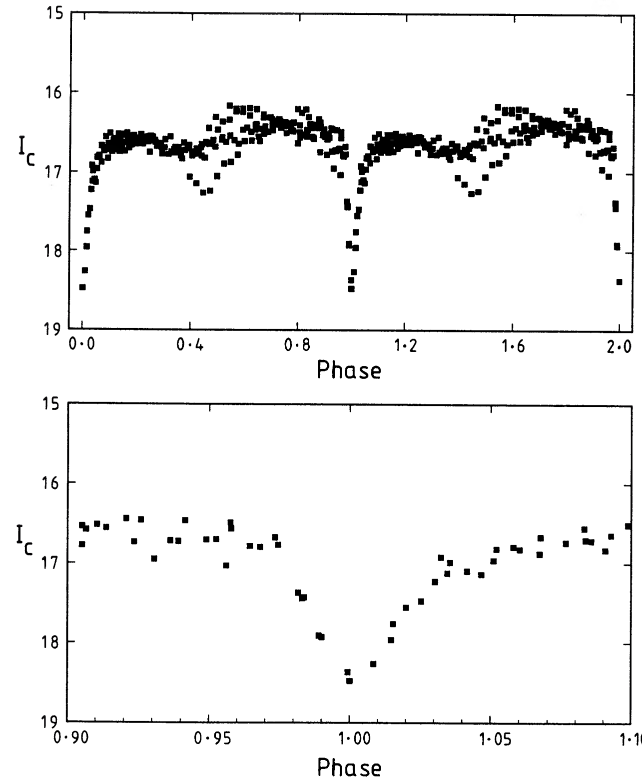

Figure 4. Top panel: I_c photometry of RXJ 0929.1 – 2404 folded over the eclipse period and plotted twice. Bottom panel: detailed representation of the eclipse.

for the Chandrasekhar-mass white dwarf ($q \sim 0.22$) is $i \sim 80°$. On the other hand, if we assume a stable mass transfer (i.e. $q < 1.0$), the smallest possible inclination is $i \sim 68°$ (for $q = 1.0$ and $\phi_{1/2} = 0°$).

3 CONCLUSION

We have demonstrated a 3.39-h optical eclipse of the X-ray source RXJ 0929.1 – 2404, which we interpret as the orbital period of the system. Although we lack polarimetric data, the X-ray and the optical characteristics of the system suggest that RXJ 0929.1 – 2404 is a new AM Herculis binary (polar). Among six known eclipsing polars, RXJ 0929.1 – 2404 is the only system with an orbital period above the 'period gap'. Detailed studies using spectral and X-ray/optical photometric data with high time resolution will provide strong constraints on the orbital inclination, the location of the accretion and emission-line regions and the masses of the stellar components. It will be possible to determine whether this system belongs to the low-mass group ($M_{\mathrm{WD}} = 0.6$–$0.7\ \mathrm{M}_{\odot}$; C evolution) or the high-mass group ($M_{\mathrm{WD}} = 1.0$–$1.4\ \mathrm{M}_{\odot}$; BB evolution) of Hameury et al. (1989). Thus further studies of RXJ 0929.1 – 2404 are especially important to models of the secular evolution of polars.

ACKNOWLEDGMENTS

The authors thank Dr R. S. Stobie for his comments. We acknowledge the use of the DoPHOT CCD reduction package by P. L. Schechter, which is supported through NSF grant AST 83-18504. BB acknowledges the support of FRD for his summer studentship at SAAO.

REFERENCES

Buckley D. A. H. et al., 1993, MNRAS, 262, 93
Chanan G. A., Middleditch J., Nelson J. E., 1976, ApJ, 208, 512
Hameury J. M., King A. R., Lasota J. P., Livio M., 1989, MNRAS, 237, 835
Mateo M., Schechter P. L., 1989, in Grosbol P. J., Murtagh F., Warmels R. H., eds, ESO Conf. & Workshop Proc. No. 31, 1st ESO/ST-ECF Data Analysis Workshop. ESO, Garching, p. 69
Menzies J. W., Cousins A. W. J., Banfield R. M., Laing J. D., 1989, S. Afr. Astron. Obs., Circ., 13, 1
Patterson J., 1984, ApJS, 54, 443
Schwope A. D., Thomas H.-C., Beuermann K., 1993, A&A, 271, L25